MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2 , 2015/2016

EPM4066 – ROBOTICS AND AUTOMATION
(ME)

10 MARCH 2016
2:30 p.m – 4:30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of **5 pages** including cover page with **4 Questions** only.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

QUESTION 1

The 3-DOF (RPR) manipulator arm is shown in **Figure Q1**.

(a) Determine the frame assignment. **[8 marks]**

(b) Determine the joint link parameter **[4 marks]**

(c) Obtain the overall homogeneous transformation matrix. **[8 marks]**

(d) Calculate the rotation matrix that describes the orientation of the tool relative to the base frame for $q = [30^o\ 20\ 60^o]^T$. **[5 marks]**

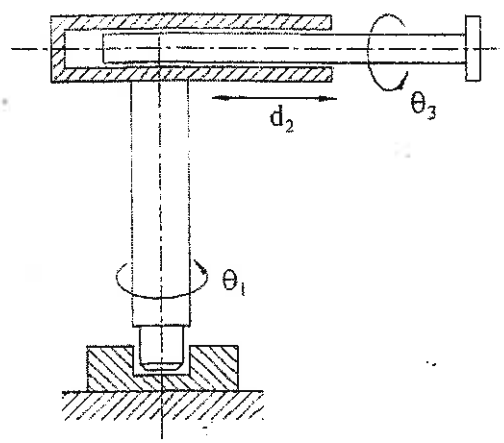

Figure Q1

QUESTION 2

(a) Explain briefly lift off point and set down point. **[5 marks]**

(b) One joint of an articulated robot shall go from initial angle 20° to a final angle of 80° in 4.5 seconds. Calculate the coefficients for a third order polynomial joint space trajectory, and sketch the plot for the joint angle, velocities, and accelerations by computing the values for the times t=0 sec, 1.5 sec, and 4.5 sec. The robot starts from rest, but is supposed to have a final velocity of 5 degree/sec. **[20 marks]**

Continued...

QUESTION 3

(a) The hand frame of a robot with five degrees of freedom (T_6), its numerical Jacobian for this instant (J) and a set of different motions are given. The robot has a 2RP2R configuration. It is assumed that the robot can only rotate about the x- and y- axes. Find the new location of the hand after the differential motion. **[15 marks]**

$$T_6 = \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 0 & -1 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$J = \begin{bmatrix} 3 & 0 & 0 & 0 & 0 \\ -2 & 0 & 1 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ -1 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} d\theta_1 \\ d\theta_2 \\ ds_1 \\ d\theta_4 \\ d\theta_5 \end{bmatrix} = \begin{bmatrix} 0.1 \\ -0.1 \\ 0.05 \\ 0.1 \\ 0 \end{bmatrix}$$

(b) For a spherical robot, the three components of the velocity of hand frame for a corresponding location is given by:

$$\begin{bmatrix} dp_x \\ dp_y \\ dp_z \end{bmatrix} = \begin{bmatrix} \sin\beta\cos\gamma & r\cos\beta\cos\gamma & -r\sin\beta\sin\gamma \\ \sin\beta\sin\gamma & r\cos\beta\sin\gamma & r\sin\beta\sin\gamma \\ \cos\beta & -r\sin\beta & 0 \end{bmatrix} \cdot \begin{bmatrix} dr \\ d\beta \\ d\gamma \end{bmatrix}$$

where $\begin{bmatrix} \sin\beta\cos\gamma & r\cos\beta\cos\gamma & -r\sin\beta\sin\gamma \\ \sin\beta\sin\gamma & r\cos\beta\sin\gamma & r\sin\beta\sin\gamma \\ \cos\beta & -r\sin\beta & 0 \end{bmatrix}$ is the Jacobian.

Calculate the required three joint velocities that will generate the following hand frame velocity:

$\dot{x} = 5\ in/sec$
$\dot{y} = 9\ in/sec$
$\dot{z} = 6\ in/sec$
$\beta = 60°$
$r = 20$ in

[10 marks]

Continued...

QUESTION 4

The **Table Q4** defines the precedence relationships and element times for a new model toy.

Table Q4. The Precedence Relationships and Element Times

Element	T_e (min)	Immediate predecessors
1	11	-
2	3	1
3	4	2
4	6	2
5	6	2
6	8	2
7	3	3,4
8	5	5
9	7	7
10	6	6,8
11	4	9,10
12	13	11

(a) Construct the precedence diagram for this job. **[5 marks]**

(b) If the ideal cycle time is to be 20.0 min, repositioning time is 2.0 min, and uptime proportion is assumed to be 1.0, what is the theoretical minimum number of stations required to minimize the balance delay? **[8 marks]**

(c) Determine the assignment of work elements to stations using the Kilbridge and Wester method. **[8 marks]**

(d) Compute the balance delay. **[4 marks]**

Continued...

Appendix

Procedure to DH-Parameter

1. Number the joints from 1 to n starting at the base and ending with the tool yaw, pitch and roll, in that order.
2. Assign a right-handed orthonormal coordinate frame L_0 to the robot base, making sure that z^0 aligns with the axis of joint 1. Set $k=1$.
3. Align z^k with the axis of joint $k+1$.
4. Locate the origin of L_k at the intersection of the z^k and z^{k-1} axes. If they do not intersect, use the intersection of z^k with a common normal between z^k and z^{k-1}.
5. Select x^k to be orthogonal to both z^k and z^{k-1}. If z^k and z^{k-1} are parallel, point x^k away from z^{k-1}.
6. Select y^k to form right-handed orthonormal coordinate frame L_k and set $k=k+1$. If $k<n$, go to step 3; else continue.
7. Set the origin of L_n at the tool tip. Align z^n with the approach vector, y^n with the sliding vector
   and x^n with the normal vector of the tool. Set $k=1$.
8. Locate point b^k at the intersection of the x^k and z^{k-1} axes. If they do not intersect, use the intersection of x^k with a common normal between x^k and z^{k-1}.
9. Compute θ_k as the angle of rotation from x^{k-1} to x^k measured about z^{k-1}.
10. Compute d_k as the distance from the origin of frame L_{k-1} to point b^k measured along z^{k-1}.
11. Compute a_k as the distance from the point b^k to the origin of frame L_k measured along x^k.
12. Compute α_k as the angle of rotation from z^{k-1} to z^k measured about x^k.
13. Set $k=k+1$. If $k \leq n$, go to step 8; else stop.

Generic DH-Transformation Matrix

$$T_{k-1}^{k} = \begin{bmatrix} C\theta_k & -S\theta_k C\alpha_k & S\theta_k S\alpha_k & a_k C\theta_k \\ S\theta_k & C\theta_k C\alpha_k & -C\theta_k S\alpha_k & a_k S\theta_k \\ 0 & S\alpha_k & C\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

End of Paper